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**Electro Scientific Industries**

13900 N.W. SCIENCE PARK DRIVE • PORTLAND, OREGON 97229

VOLTMETERS

APRIL 1966
REPLACES SEPTEMBER 1965

MODEL

# 330

*Instruction Manual*

# POTENTIOMETRIC DC VOLTMETER

SERIAL NUMBER: _____

PART NUMBER: 18083

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The following table lists the most recent revision of each page at the present date of printing:

| Page | Date |
|---|---|
| Title | 4/66 |
| A | 4/66 |
| i | 9/65 |
| ii | 9/65 |
| 1-1 thru 1-3 | 9/65 |
| 1-4 and 1-5 | 4/66 |
| 1-6 | 9/65 |
| 2-1 thru 2-11 | 9/65 |
| 3-1 thru 3-4 | 9/65 |
| 4-1 thru 4-5 | 9/65 |
| 4-6 thru 4-8 | 4/66 |
| 4-9 thru 4-16 | 9/65 |
| Appendix | 9/65 |

TABLE OF CONTENTS


I INTRODUCTION
- 1.1 DESCRIPTION 1-1
- 1.2 SPECIFICATIONS 1-4
- 1.3 APPLICATIONS 1-6

II OPERATION
- 2.1 GENERAL 2-1
  - 2.1.1 Controls, Connections, and Indications 2-1
  - 2.1.2 Battery Life and Battery Check 2-2
  - 2.1.3 Null Balancing 2-3
  - 2.1.4 Meter Interpolation 2-4
- 2.2 OPERATING INSTRUCTIONS 2-6
  - 2.2.1 Voltage Measurement 2-6
  - 2.2.2 Standard Voltage Source 2-8
- 2.3 DETECTOR CONNECTIONS 2-11
  - 2.3.1 External Detector 2-11
  - 2.3.2 Detector Output 2-11

III THEORY
- 3.1 GENERAL 3-1
- 3.2 POTENTIOMETRIC VOLTMETER 3-1
  - 3.2.1 Voltage Reference 3-1
  - 3.2.2 Potentiometer 3-1
  - 3.2.3 Detector 3-3
  - 3.2.4 Input Attenuator 3-3
  - 3.2.5 Guarding 3-4

IV MAINTENANCE
- 4.1 CHECKOUT 4-1
  - 4.1.1 Mechanical Checks 4-1
  - 4.1.2 Null Detector Sensitivity Test 4-2
  - 4.1.3 Stability Test 4-2
  - 4.1.4 Main Decade Self-Check 4-2
- 4.2 CALIBRATION 4-4
  - 4.2.1 Standard Cell Calibration 4-4
  - 4.2.2 Range Calibration 4-5
  - 4.2.3 Main Decade Calibration 4-8
- 4.3 TROUBLESHOOTING 4-12
  - 4.3.1 Troubleshooting Table 4-12
  - 4.3.2 Removing the Instrument Case 4-13
- 4.4 REPLACEMENT PARTS 4-14

APPENDIX

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DEKATRAN Decade Transformer

# ESI MODEL 330 POTENTIOMETRIC VOLTMETER

## INSTRUCTION MANUAL

## SECTION I

## INTRODUCTION

### 1.1 DESCRIPTION

The ESI Model 330 Potentiometric Voltmeter is a battery-operated dc voltage measurement system. The instrument consists of a precision five-dial potentiometer with independently calibrated ranges, a regulated working voltage supply, a thermally-lagged unsaturated standard cell voltage reference, and a solid-state electronic detector.

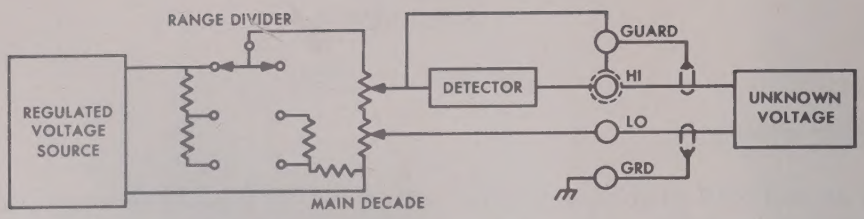
Battery operation eliminates power-line problems and allows floating operation. The solid-state electronic devices allow the instrument to be operated without warm-up, and with only one minute for stabilization.

There has been no compromise with quality in the resistors. The resistors have been aged, the resistances and temperature coefficients have been matched, and range trimmers have been provided to maintain the initial accuracy for many years.

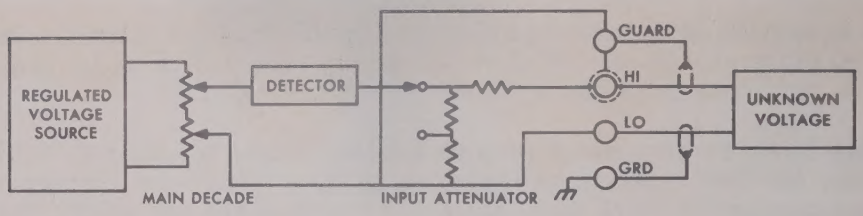
The instrument is fully potentiometric for the 120-millivolt, 1200-millivolt, and 12-volt ranges and uses a 10-megohm input attenuator for the 120-volt and 1200-volt ranges. The instrument is guarded internally and the GUARD terminal supplies a guard potential for the shield of one test lead, thus ensuring uncompromised guarding from the instrument to the voltage to be measured. The guarding eliminates errors that are due to leakage.

Figure 1.1 shows simplified diagrams of the instrument set for potentiometric measurements, divided-voltage measurements, and for working voltage standardizing.

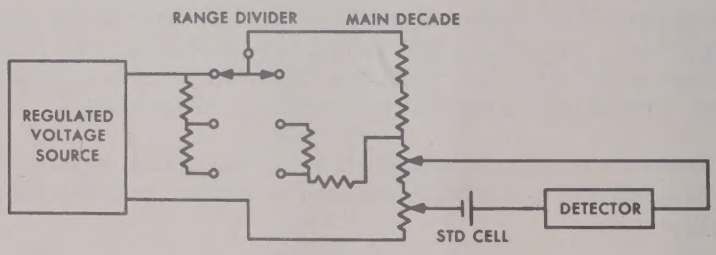
Operating instructions for voltage measurement and standard cell calibration are attached to the inside of the instrument lid. Figure 1.2 shows the operating instructions.




POTENTIOMETRIC VOLTAGE MEASUREMENT

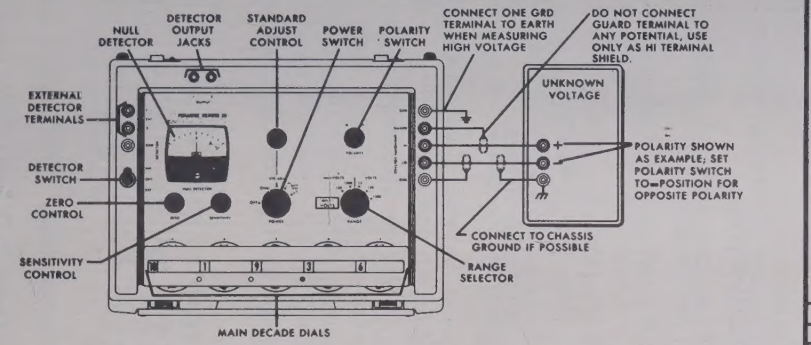


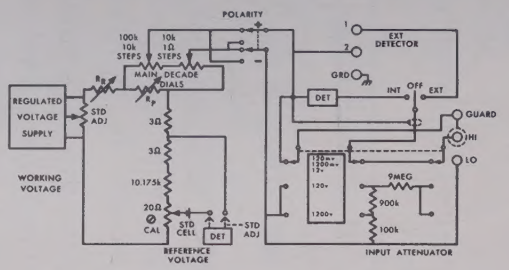

DIVIDED-VOLTAGE MEASUREMENT




STANDARDIZING

Figure 1.1 Simplified Diagrams


NULL DETECTOR
DETECTOR OUTPUT JACKS
STANDARD ADJUST CONTROL
POWER SWITCH
POLARITY SWITCH
CONNECT ONE GRD TERMINAL TO EARTH WHEN MEASURING HIGH VOLTAGE
DO NOT CONNECT GUARD TERMINAL TO ANY POTENTIAL, USE ONLY AS HI TERMINAL SHIELD.
UNKNOWN VOLTAGE
EXTERNAL DETECTOR TERMINALS
DETECTOR SWITCH
ZERO CONTROL
SENSITIVITY CONTROL
POLARITY SHOWN AS EXAMPLE; SET POLARITY SWITCH TO — POSITION FOR OPPOSITE POLARITY
CONNECT TO CHASSIS GROUND IF POSSIBLE
RANGE SELECTOR
MAIN DECADE DIALS




| RANGE | 120mv | 1200mv | 12v | 120v | 1200v |
|---|---|---|---|---|---|
| $R_B$ | 121k | 110k | 0 | | |
| $R_P$ | 1235Ω | 13.58k | OPEN | | |

## VOLTAGE MEASUREMENT

**A. Turn on power and stabilize.**

1. Turn POWER switch to BATT TEST positions. In each position, NULL DETECTOR pointer should be in BATT OK brackets.
2. Set POWER switch to ON; allow approximately one minute for stabilization.

**B. Adjust detector zero.**

1. Set DETECTOR switch to OFF.
2. Set SENSITIVITY control fully clockwise.
3. Adjust ZERO control for NULL DETECTOR zero indication.

**C. Connect unknown voltage as shown in illustration.**

**D. Set POLARITY switch to polarity of HI terminal.**

If polarity is unknown:

1. Set all main decade dials to zero.
2. Set SENSITIVITY control fully counterclockwise.
3. Set DETECTOR switch to INT.
4. If NULL DETECTOR pointer moves left of zero, set POLARITY switch to —; if pointer moves right of zero, set POLARITY switch to +.
5. Set DETECTOR switch to OFF.

**E. Set range and decade slightly less than unknown voltage.**

If approximate voltage is not known:

1. Set RANGE selector to 1200 volts.
2. Set main decade dials to 11 0 0.0 0.
3. Set SENSITIVITY control fully counterclockwise.
4. Set DETECTOR switch to INT.
5. Turn RANGE selector slowly counterclockwise until NULL DETECTOR indication reverses polarity, then turn selector back one step.
6. Turn main decade dial A slowly counterclockwise until NULL DETECTOR indication reverses polarity.
7. Set DETECTOR switch to OFF.

**F. Standardize working voltage.**

1. Set SENSITIVITY control fully clockwise.
2. Set POWER switch to STD ADJ position.
3. Set DETECTOR switch to INT.
4. Adjust STD ADJ control (10-turn rheostat) for NULL DETECTOR zero indication.
5. Set DETECTOR switch to OFF.
6. Set POWER switch to ON.

**G. Make final balance.**

1. Set SENSITIVITY control fully counterclockwise.
2. Set DETECTOR switch to INT.
3. Turn main decade dial B slowly clockwise until NULL DETECTOR indication reverses polarity, then turn dial back one step.
4. Increase gain of SENSITIVITY control (clockwise) until NULL DETECTOR indicates slightly less than full scale or until control reaches its limit.
5. Similarly, balance with main decade dials C, D, and E.
6. Adjust detector zero (step B) and standardize working voltage (step F).
7. Rebalance with main decade dials if necessary.

**H. Read the value of the unknown voltage from the main decade dials.**

**I. Disconnect unknown voltage and turn off power.**

1. Disconnect leads from unknown voltage. Leads may be stored between instrument and lid.
2. Set POWER switch to OFF before leaving instrument.

*CAUTION:*

PROTECT INSTRUMENT FROM EXTREME TEMPERATURES. The standard cell will freeze and break at approximately —35°F (—36°C), and will be damaged by temperatures higher than 160°F (75°C). For best accuracy, operate the instrument at temperatures between 40°F (5°C) and 135°F (57°C).

## STANDARD CELL CALIBRATION

The reference voltage in the Model 330 Potentiometric Voltmeter is a thermally lagged unsaturated standard cell. In order to maintain 0.001% accuracy of the standard cell, calibrate every 60 days by measuring a certified saturated cadmium standard cell; adjust as follows only if necessary.

1. Remove battery compartment cover for access to standard cell adjustment control.
2. Turn on power and stabilize.
3. Adjust detector zero.
4. Set RANGE selector to 1200 MILLIVOLTS.
5. Set main decade dials to the certified voltage of the standard cell. Main decade dial A should be set at 10 and main decade dial B should be set at 1 for saturated or unsaturated standard cells.
6. Set POLARITY switch to +.
7. Connect UNKNOWN VOLTAGE terminals to standard cell, HI terminal to positive standard cell terminal.
8. Set DETECTOR switch to INT.
9. Adjust STD ADJ control on front panel for NULL DETECTOR zero indication.
10. Set POWER switch to STD ADJ and adjust standard cell adjustment control in battery compartment for NULL DETECTOR zero indication.
11. Set POWER switch to ON and make sure that NULL DETECTOR indicates zero.
12. Disconnect instrument from standard cell and replace battery compartment access door.

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Figure 1.2 Operating Instructions

## 1.2 SPECIFICATIONS

Ranges:

| VOLTMETER | MIN STEP | REFERENCE VOLTAGE SOURCE | MIN STEP |
|---|---|---|---|
| (1) 0 TO 121.110 MILLIVOLTS | 1 μV | (1) 0 TO 121.110 MILLIVOLTS | 1 μV |
| (2) 0 TO 1211.10 MILLIVOLTS | 10 μV | (2) 0 TO 1211.10 MILLIVOLTS | 10 μV |
| (3) 0 TO 12.1110 VOLTS | 100 μV | (3) 0 TO 12.1110 VOLTS | 100 μV |
| (4) 0 TO 121.110 VOLTS | 1 mV | | |
| (5) 0 TO 1211.10 VOLTS | 10 mV | | |

Accuracy:

Five Dial Decade Potentiometer: ±(10 ppm of reading plus 1 ppm of full scale)

Range Ratio Accuracy: No ratio error on calibrating range, 10 ppm on other ranges.

Stable trimmers provide ratio adjustment to maintain initial accuracies.

Thermoelectric Voltages: Less than 1 microvolt

Warranted Accuracy:

The error of the instrument is warranted to be less than the square root of the sum of the squares of the limits of error of the contributing factors. These limits are shown for several voltages in the following tables. The factors listed as "Working Voltage" and "Calibration" represent the accuracy to which the instrument can be calibrated and the working voltage can be standardized with the internal detector.

| FACTOR | LIMITS OF ERROR (ppm) | | | | |
|---|---|---|---|---|---|
| | 1000V | 100V | 10V | 1V | 100mV |
| POTENTIOMETER (maximum) | 11 | 11 | 11 | 11 | 11 |
| RANGE RATIO | 10 | 10 | 10 | 0 | 10 |
| CALIBRATION | 5 | 5 | 5 | 5 | 5 |
| WORKING VOLTAGE | 5 | 5 | 5 | 5 | 5 |
| DETECTOR | 0.5 | 0.5 | 0.5 | 5 | 50 |
| THERMOELECTRIC VOLTAGE | 0.1 | 0.1 | 0.1 | 1 | 10 |
| WARRANTED ACCURACY (WITHOUT STANDARD CELL) | 17 | 17 | 17 | 14 | 54 |

| TYPE OF ACCURACY | LIMITS OF ERROR (ppm) | | | | |
|---|---|---|---|---|---|
| | 1000V | 100V | 10V | 1V | 100mV |
| WARRANTED ACCURACY (WITHOUT STANDARD CELL) | 17 | 17 | 17 | 14 | 54 |
| STANDARD CELL IN LABORATORY ENVIRONMENT (30-DAY) | 10 | 10 | 10 | 10 | 10 |
| WARRANTED 30-DAY ACCURACY IN LABORATORY ENVIRONMENT | 20 | 20 | 20 | 17 | 55 |
| STANDARD CELL IN FIELD CONDITIONS (6-MONTH) | 40 | 40 | 40 | 40 | 40 |
| WARRANTED 6-MONTH ACCURACY IN FIELD CONDITIONS | 44 | 44 | 44 | 43 | 68 |

Perf. Check

The accuracy of the standard cell depends on the temperature environment of the instrument. Immediately after calibration it is ±5 ppm (included in the table as "Calibration"). Under laboratory conditions with temperature controlled to ±3°C (with changes less than ±1°C per hour) the standard cell voltage will remain within ±10 ppm for more than 30 days. With less stringent temperature control, such as field conditions, the voltage will remain within ±40 ppm for more than 6 months.

Temperature Coefficient: Less than ±10 ppm of reading per degree C above one-tenth of full scale on all ranges.

Input Impedance: Infinite at null on ranges 1, 2 and 3. Ten megohms on ranges 4 and 5.

Reversing Switch: Provides for polarity reversal.

Working Voltage: Two-stage Zener regulation and long life mercury cells to insure maximum working voltage stability.

50,000

Guarding: Batteries, null detector and potentiometer on individual chassis well insulated from each other and from case ground.

Minimum insulation resistance $10^{11}$ ohms.

The circuit ground of the Model 330 may be operated as much as ±600 volts with respect to case ground.

Overvoltage Protection: Up to 1,211 volts may be applied to the input terminals with any control setting, without damaging the instrument.

Null Detector:

Minimum Detectable Signal: 5 microvolts or better.

Scale Deflection: Linear meter deflection over full scale range to permit interpolation between switch steps.

Input Impedance: Approximately 1 megohm.

Zero Stability: ±5 microvolts or better long term.

AC Rejection: At least 70 dB at 50 cps improving at all higher frequencies.

Sensitivity: Continuously variable through 80 dB range.

Zero Suppression: Zero suppression control provides up to ±200 microvolts to offset externally produced thermal voltages.

Overload Protection: Up to 1200 volts may be applied across the input terminal at any sensitivity setting without damage.

Overload Recovery Time: Within 5 seconds for overloads of 10,000 times minimum detectable signal. Recovery within 60 seconds for overloads up to 1200 volts.

Common Mode AC Rejection: Battery operation and shielding completely isolate instrument from power lines and eliminate common mode ac pickup.

Stabilization Time: Sixty seconds or less after switching on batteries.

Recorder Output: 50 millivolts dc full scale with approximately 1-kilohm output resistance. Recorder must have input fully isolated from ground. ($10^{10}$ ohms minimum leakage)

Solid State Amplifier: Only silicon diodes, silicon transistors, tantalum capacitors, epoxy glass circuit boards, and similar high-quality components used for long circuit life.

Batteries: Four size D cells
Three 8.4-volt mercury batteries.

Battery Life: Approximately 1000 hours for all batteries.

Power Consumption: 6 volts at 5 milliamperes, 30 milliwatts;
25.2 volts at 0.7 milliamperes, 17.6 milliwatts.

Size: Length 36.9 cm (14.5"), width 28.7 cm (11.3"), height 18.3 cm (7.2")

Weight: 8.4 kg (18.5 lb)

Accessories Supplied: Test leads, instructions, batteries.

## 1.3 APPLICATIONS

The primary use of the Model 330 Potentiometric Voltmeter is precise measurement of voltages from a few microvolts to 1211.10 volts. It is not possible to enumerate all possible uses of precision voltage measurement, but we have listed below some typical applications. If you have an unusual application or a question concerning some use of the instrument, let us know. Write to: Technical Services, Electro Scientific Industries, 13900 N. W. Science Park Drive, Portland, Oregon 97229.

The Model 330 may be used to calibrate digital voltmeters, laboratory potentiometers, voltage dividers, recorder-controllers, x-y recorders, millivoltmeters, voltmeters, differential voltmeters, and voltage transducers. Because of its portability and battery operation, it is ideal for field calibration of voltage measuring and recording equipment.

The Model 330 may be used for potentiometric measurements of temperature with base or noble metal thermocouples, and of electrochemical voltages such as pH and redox.

The instrument may be used to measure and monitor small voltage changes. External detector connections and detector output jacks make it possible to operate recorders and controllers with the instrument; either the device being operated or the voltage being measured must be isolated from ground by $10^{10}$ ohms or more.

## SECTION II

## OPERATION

### 2.1 GENERAL

The ESI Model 330 Potentiometric Voltmeter is a battery-operated dc voltage measuring system. Operation of the instrument is similar to operation of many other potentiometric instruments. The basic operating steps are described on the short-form instruction sheet inside the instrument lid.

#### 2.1.1 Controls, Connections, and Indications

The controls and connections necessary to operate the Model 330 Potentiometric Voltmeter are illustrated in Figure 2.1. A brief description of each follows:

The main decade dials are the null balancing controls and provide a five-digit in-line readout. The X position on each dial except the first provides a ten-percent range overlap. All dials except the first may be continuously rotated; that is, rotated directly from 0 to X as well as from 0 to X by way of 1, 2, 3, etc.

The NULL DETECTOR meter provides an indication of potentiometric null and may be used in most cases for interpolation of one digit more than provided by the five-digit main decade dials.

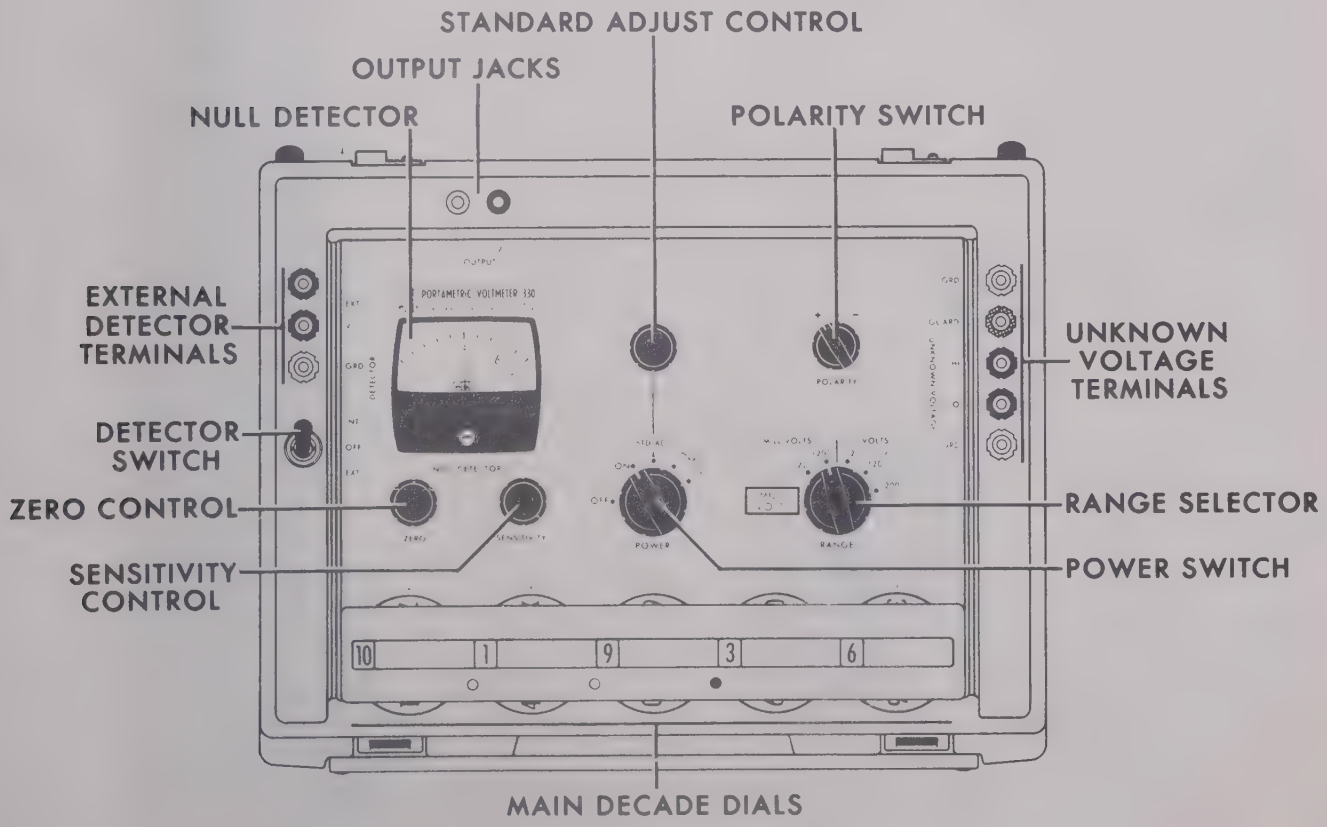
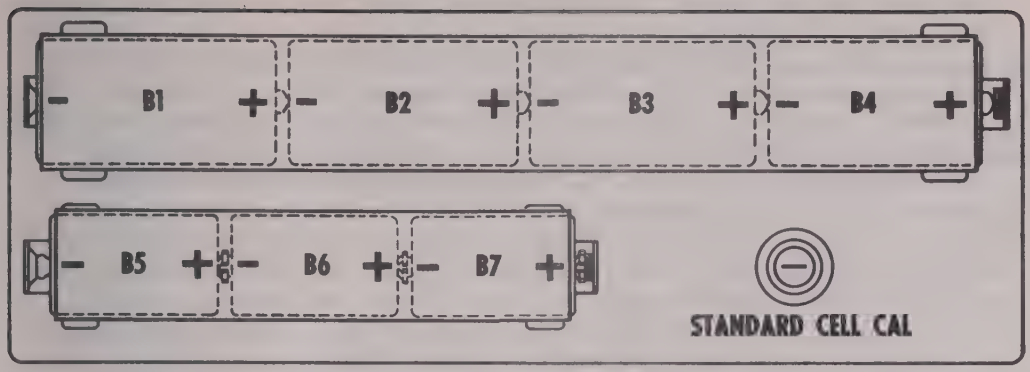



Figure 2.1 Controls and Connections




B1 THRU B4 ARE 1.5v 'D' CELL ZINC-CARBON E950 OR EQUIVALENT.
B5 THRU B7 ARE 8.4v MERCURY BATTERIES , EVEREADY E 286 OR EQUIVALENT.

Figure 2.2 Battery Locations

BATT TEST position 1 of the POWER switch, tests the four D cells B1 through B4. BATT TEST position 2 tests the three mercury batteries B5, B6, and B7.

### 2.1.3 Null Balancing

Making measurements with the Model 330 Potentiometric Voltmeter requires balancing a potentiometer. Here are a few hints to assist the user in finding a null.

No damage will be done to the instrument by leaving the SENSITIVITY control at maximum (fully clockwise) and seeking a null. Usually the NULL DETECTOR pointer snaps from one end of full scale to the other when the setting of the first two or three main decade dials is turned past the balancing point. But when one is seeking a first approximation to a null, it is better to decrease the sensitivity of the detector so that the pointer indicates something less than full scale. As the setting of each of the main decade dials approximates the balance point, (one dial division before the detector indicates a reversed polarity), the sensitivity should be increased so that the NULL DETECTOR indicates something less than full scale again. Then proceed with the next decade dial.

Another advantage of decreasing the sensitivity is that it makes searching for an unknown value easier. If the pointer approaches zero when you turn one of the main decade dials, you know that you are going in the right direction.

The step-by-step operating instructions are written with the assumption of the worst case (i.e., that the range and the value of the unknown are completely unknown). For this reason, the operating instructions describe a process that searches through all ranges and values for a null. In most cases, that is not necessary. The approximate value of the unknown, is usually known. If you have some idea of the value of the unknown, set the RANGE selector and the first main decade dial to the approximate value of the unknown, and then proceed according to the step-by-step instructions.

The main decade dials, except for the first, can be rotated through a full circle. There are eleven positions marked on each of these four switches, of which the eleventh position is marked X. The X position corresponds to 1 on the next higher switch. That is, 1.998X is equal to 1.9990, and 1.0000 is equal to 0.X000, 0.9X00, 0.99X0, and 0.999X. This feature is quite useful when one is measuring quantities near the integer points. As an example, suppose that it is necessary to measure a voltage that is approximately 100 volts. If the RANGE selector is set to 120 VOLTS, and the main decade dials are set to 99.99X at null, the measurement is 100.00 volts. If the dials are at 99.9X3, the measurement is 100.03 volts, and if the dials are set to 99.997, the measurement is 0.03 volts less than 100 volts. Notice that it is only necessary to move the last two dials when the measurement is changed from 100.03 volts to 99.97 volts. A change of measurement of this sort can be quite frustrating on an instrument that has only ten positions, because all five dials have to be changed. It is even worse when the dials cannot be turned directly from 9 to 0, but have to be turned from 9 to 8 to 7 and around to 0.

### 2.1.4 Meter Interpolation

In many measurement applications, it is possible to interpolate with the NULL DETECTOR indication. Usually it is not possible to get an exact null indication with the main decade dials, but the null will lie between switch steps of main decade dial E. The NULL DETECTOR indication will be to the left of zero on one dial setting, and to the right of zero one switch step away. To use the NULL DETECTOR indication for interpolation, use the following procedure:

(1) Obtain the nearest approach to a null that is possible. Complete instructions are in Section 2.2.

(2) Note the NULL DETECTOR indication for the two adjacent switch steps of main decade dial E that are nearest to the null. The indications will be on each side of zero.

(3) Let M be the NULL DETECTOR indication when main decade dial E is on the lower of the two adjacent switch steps, and let N be the NULL DETECTOR indication for the higher switch step x. Add the following interpolation fraction to the lower of the two switch steps:

$$\frac{M}{M+N}$$

For example: The voltage of a dry cell x is measured. When the main decade dials are set to 1.4872, the NULL DETECTOR pointer is 8 dots from zero, when the main decade dials are set to 1.4873, the NULL DETECTOR pointer is 5 dots on the other side of zero. The interpolation fraction is:

$$\frac{8}{5+8} = \frac{8}{13}$$

Since 8/13 is approximately equal to 0.6, the interpolated main decade dial reading is 1.48726.

It is often possible to adjust the SENSITIVITY control so that the detector pointer moves ten divisions when the decade dial is moved one step. This sets the denominator, M + N, of the interpolation fraction to 10, and the numerator, M, is interpolated directly as an additional digit.

## 2.2 OPERATING INSTRUCTIONS

Voltage measurement is the basic function of the Model 330 Potentiometric Voltmeter. All other functions of the instrument derive from voltage measurement; operating instructions for other functions of the instrument refer to the basic steps of voltage measurement. The basic steps are listed inside the instrument lid and in paragraph 2.2.1.

### 2.2.1 Voltage Measurement

A. Turn on power and stabilize.

1. Turn POWER switch to BATT TEST positions. In each position, NULL Detector pointer should be inside BATT OK bracket.
2. Set POWER switch to ON; allow approximately one minute for stabilization.

B. Adjust detector zero.

1. Set DETECTOR switch to OFF.
2. Set SENSITIVITY control fully clockwise.
3. Adjust ZERO control for NULL DETECTOR zero indication.

C. Connect unknown voltage as shown in Figure 2.3.

D. Set POLARITY switch to polarity of HI terminal.

If polarity is unknown:

1. Set all main decade dials to zero.
2. Set SENSITIVITY control fully counter-clockwise.
3. Set DETECTOR switch to INT.
4. If NULL DETECTOR pointer moves left of zero, set POLARITY switch to -; if pointer moves to right of zero, set POLARITY switch to +.
5. Set DETECTOR switch to OFF.

E. Set range and decade slightly less than unknown voltage.

If approximate voltage is unknown:

1. Set RANGE selector to 1200 volts.
2. Set main decade dials to 11 0 0. 0 0.
3. Set SENSITIVITY control fully counter-clockwise.
4. Set DETECTOR switch to INT.
5. Turn RANGE selector slowly counter-clockwise until NULL DETECTOR indication reverses polarity, then turn selector back one step.

**CAUTION**

**Do not connect GUARD terminal to any voltage, use GUARD terminal potential for HI terminal shield only.**

6. Turn main decade dial A slowly counter-clockwise until NULL DETECTOR indication reverses polarity.
7. Set DETECTOR switch to OFF.

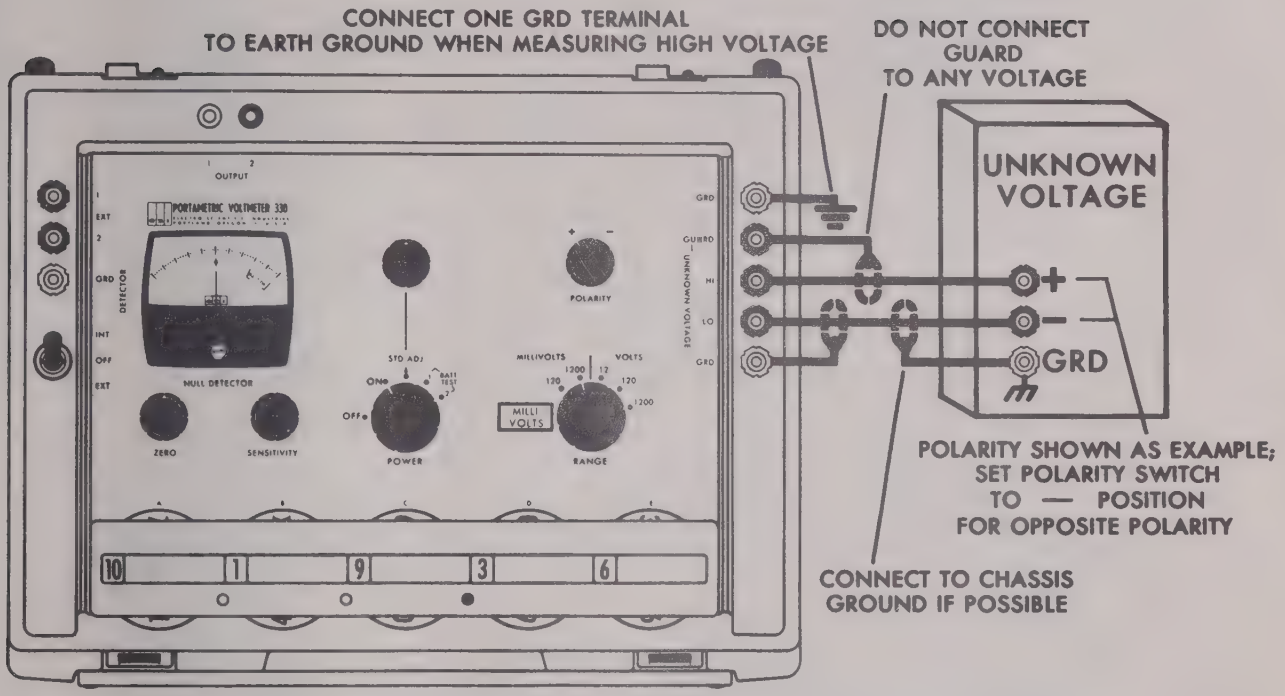



Figure 2.3 Voltage Measurement

F. Standardize working voltage.

1. Set SENSITIVITY control fully clockwise.
2. Set POWER switch to STD ADJ position.
3. Set DETECTOR switch to INT.
4. Adjust STD ADJ control (10-turn rheostat) for NULL DETECTOR zero indication.
5. Set DETECTOR switch to OFF.
6. Set POWER switch to ON.

Be sure to standardize with RANGE selector at the setting on which the measurement is to be made.

G. Make final balance.

1. Set SENSITIVITY control fully counter-clockwise.
2. Set DETECTOR switch to INT.
3. Turn main decade dial B slowly clockwise until NULL DETECTOR indication reverses, then turn dial back one step.

4. Increase gain of SENSITIVITY control (clockwise) until NULL DETECTOR indicates slightly less than full scale or until control reaches its limit.
5. Similarly, balance with main decade dials C, D, and E.
6. Adjust detector zero (step B) and standardize working voltage (step F).
7. Rebalance with main decade dials if necessary.

H. Read the value of the unknown voltage from the main decade dials.

I. Disconnect unknown voltage and turn off power.

1. Disconnect leads from unknown voltage. Leads may be stored between instrument and lid.
2. Set POWER switch to OFF before leaving instrument.

### 2.2.2 Standard Voltage Source

The Model 330 Potentiometric Voltmeter may be used as a standard voltage source on the 12-volt, 1200 millivolt, and the 120-millivolt ranges.

A. Turn on power and stabilize.

B. Adjust Detector Zero.

C. Connect a test lead between EXT DETECTOR terminals 1 and 2.

D. Connect outputs to UNKNOWN VOLTAGE terminals as required, see Figure 2.4.

E. Set RANGE selector and main decade dials to required voltage; set POLARITY switch to desired polarity.

F. Standardize working voltage.

G. Set DETECTOR switch to EXT position to apply standard voltage to output.

H. Disconnect test leads from output and especially from EXT DETECTOR terminals before leaving instrument, turn off power.

**CAUTION**

Do not connect a standard voltage supply to another voltage source. Do not leave the instrument set as a standard voltage source so that some other person might inadvertently connect it to a voltage source. Setting the Model 330 Potentiometric Voltmeter as a standard voltage source places precision resistors of the main decade across the output. Even low voltages, if the source is not power limited, may damage the resistors with the dials in certain positions.

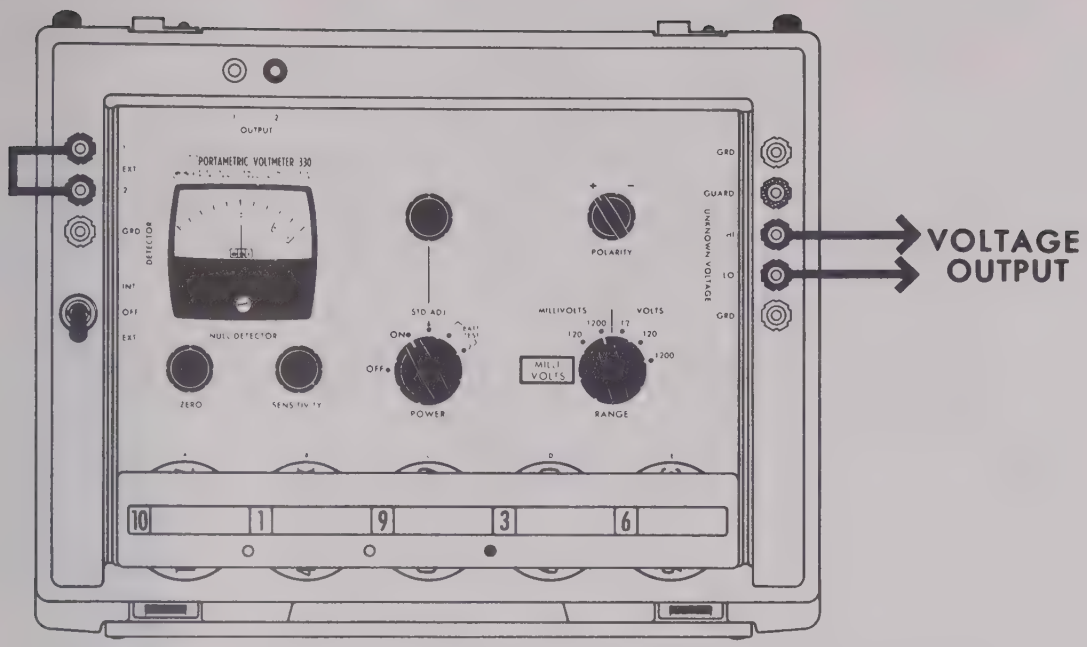



Figure 2.4 Voltage Source Connection

The standard voltage source is intended as a no-load supply. If current is drawn from the standard voltage source, the voltage will decrease. Figure 2.5 illustrates graphically the output deviation due to loading for each decade dial setting

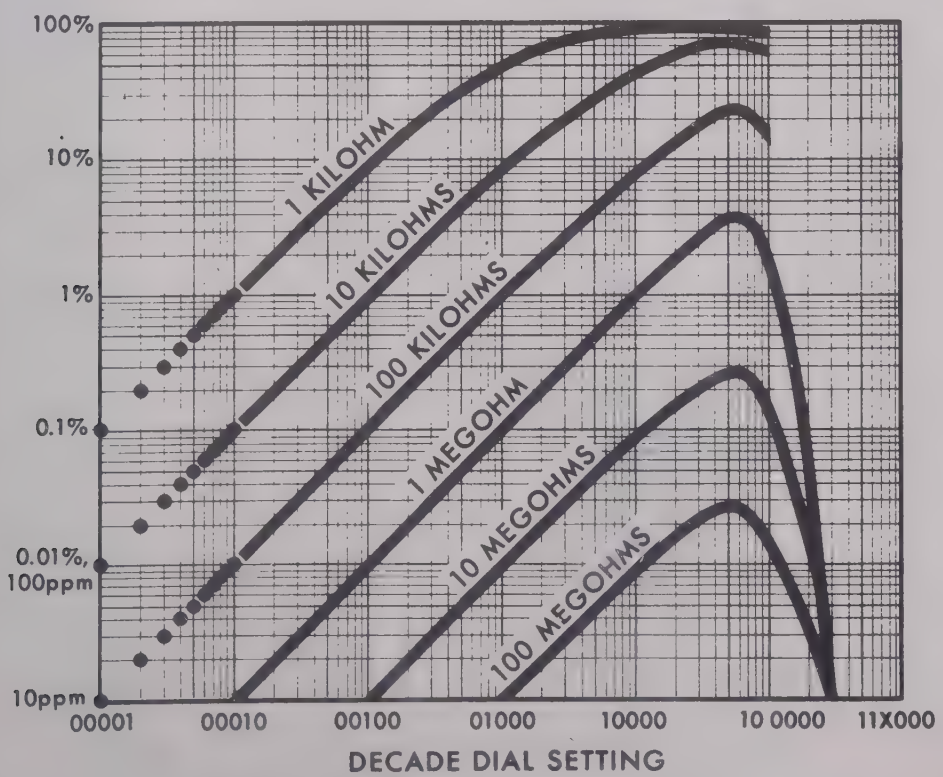



Figure 2.5 Output Deviation Due to Loading

A more exact formula for calculating the voltage is given as follows:

$$E_L = \frac{R_L S K}{R_R + R_L + S - \frac{S^2}{12221}}$$

Where $E_L$ is the voltage across the load, $R_L$ is the load resistance, and S is the setting of the main decade dials ignoring the decimal point. The other parameters differ according to the range, and are given in the following table.

| PARAMETER | RANGE | | |
|---|---|---|---|
| | 12-V | 1200-mV | 120-mV |
| K | $10^{-4}$ | $10^{-5}$ | $10^{-6}$ |
| $R_R$ | 10,200 | 11,421 | 25,500 |

## 2.3 DETECTOR CONNECTIONS

### 2.3.1 External Detector

Under some conditions, it may be desirable to use a detector other than the one that is built into the instrument. The EXT DETECTOR terminals provide a connection for another detector. It is generally best to shield the external detector and the leads that connect it to the Model 330 Potentiometric Voltmeter. No general rule can be given for shielding, but the following suggestions may be helpful.

Some detectors have both input terminals isolated from ground, and some have one input terminal connected to the detector chassis. If both input terminals are separated from ground, it is possible to connect the detector input terminals to EXT DETECTOR terminals 1 and 2, and connect the detector chassis ground (usually the input cable shield) to the GRD terminal. If the external detector has one input terminal grounded, it is usually best to connect that terminal to EXT DETECTOR terminal 2, and connect a shorting link between that terminal and the adjacent GRD terminal.

Never connect more than one operating terminal to a GRD terminal. Doing so will probably result in an erroneous reading and may damage an external detector that is not protected against overloads.

### 2.3.2 Detector Output

It is possible to use the null detector amplifier in the Model 330 Potentiometric Voltmeter to operate a remote meter, a recorder, a controller, or other device. The DETECTOR OUTPUT jacks provide a connection to the output of the detector amplifier. The output gain is variable with the SENSITIVITY control, the output zero point is variable with the ZERO control. The output voltage is about 50 millivolts full scale. The red jack is the positive terminal. Either the device operated from the amplifier or the voltage being measured must be isolated from ground by $10^{10}$ ohms or more.

CAUTION

**Do not connect any voltage to the DETECTOR OUTPUT jacks. The OUTPUT jacks are connected across the NULL DETECTOR meter which can be damaged by voltages higher than 50 millivolts.**

SECTION III

THEORY

## 3.1 GENERAL

The Model 330 Potentiometric Voltmeter is a fully potentiometric voltmeter for voltages less than 12.1110 volts, and uses a ten-megohm attenuator to divide higher voltages by 10 or 100.

## 3.2 POTENTIOMETRIC VOLTMETER

A potentiometric voltmeter can measure voltage with great accuracy because at null, it does not load the circuit from which it is measuring voltage. A potentiometric voltmeter is basically a voltage reference, a potentiometer, and a detector. Figure 3.1 illustrates a basic potentiometric voltmeter; Figure 3.2 is a more complete schematic diagram that illustrates the detailed description in the following paragraphs.

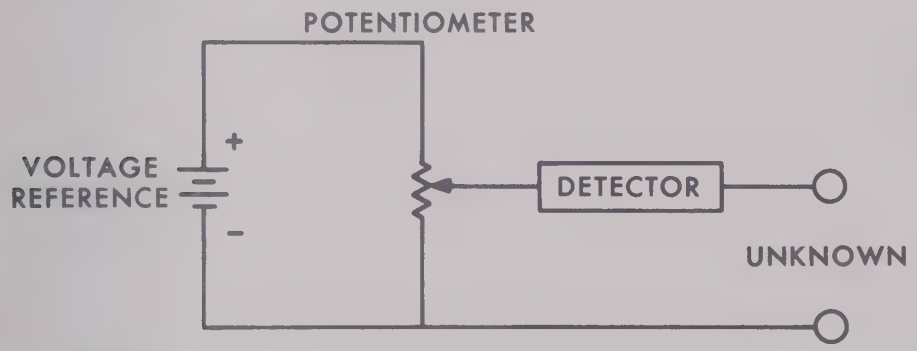



Figure 3.1 Basic Potentiometric Voltmeter

### 3.2.1 Voltage Reference

The working voltage reference in the Model 330 Potentiometric Voltmeter is a Zener-controlled series-regulated battery-powered voltage supply. The voltage output of the working voltage reference is 13.2421 volts.

The working voltage reference output is compared to the voltage of a standard cell during standardization; The circuit that compares the voltages is another potentiometric circuit.

### 3.2.2 Potentiometer

The potentiometer in the Model 330 Potentiometric Voltmeter consists of three parts, the ratio resistors, the calibration potentiometers, and the main decade potentiometer. The ratio resistors divide the reference voltage by ten or one hundred, depending on the voltage range. The calibration potentiometers supply a portion of the working voltage to be compared with a standard cell. The main decade potentiometer divides the working voltage further into precisely controlled steps.

Depending on the setting of the RANGE selector, the voltage across the

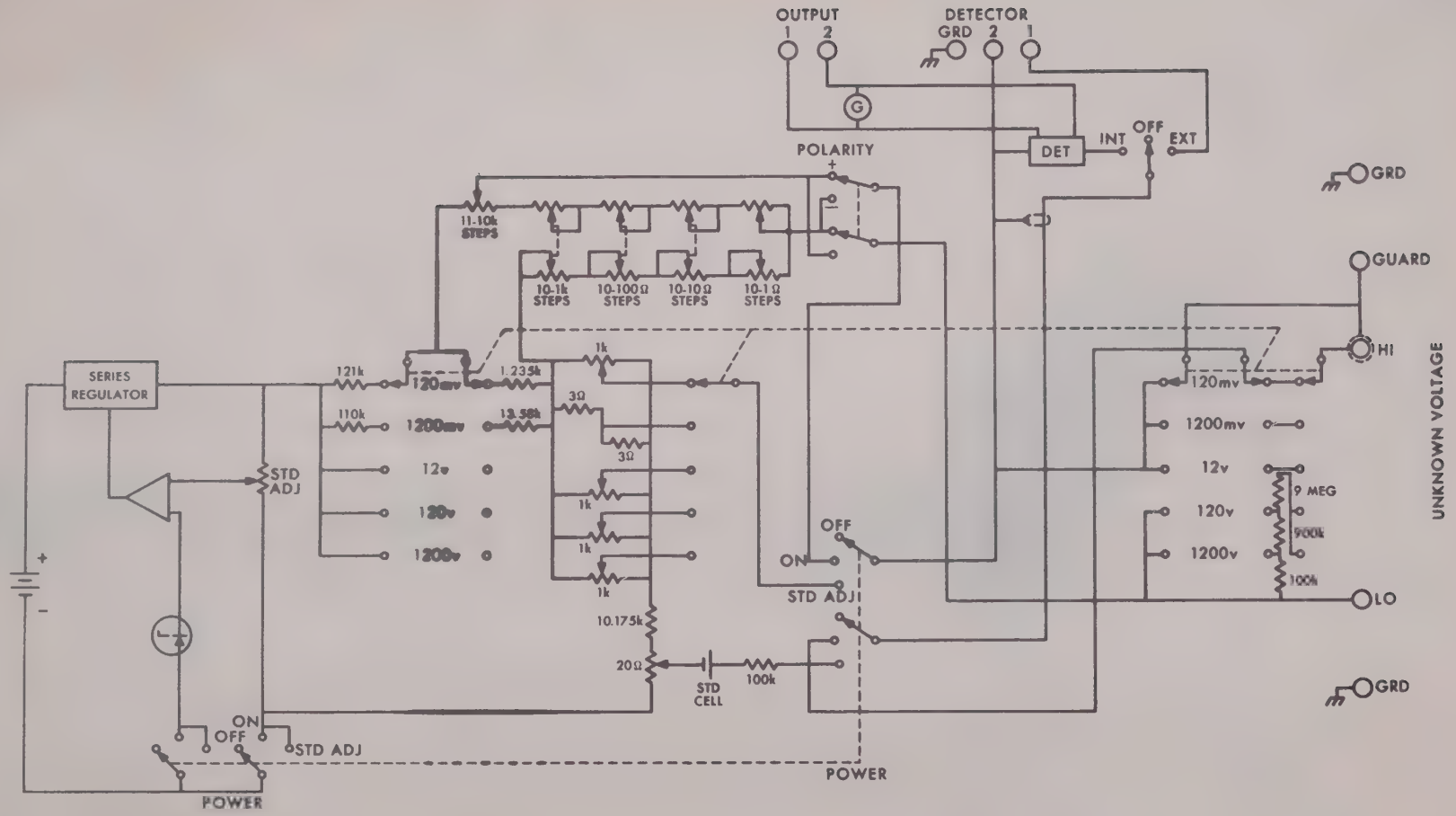



**Figure 3.2** Model 330 Schematic Diagram

main decade potentiometer is 12.2220 volts, 1.22220 volts, or 0.122220 volts. The main decade potentiometer divides this voltage into one-, ten-, or hundred-microvolt steps.

The voltage across the calibration potentiometers is 1.0200 volts. This voltage is compared potentiometrically to the voltage of a standard cell, a voltage between 1.0183 and 1.01990 volts. The standard cell adjustment allows exact compensation for different voltages of standard cell, and ratio adjustment potentiometers allow compensation for slight changes in ratio resistor values.

### 3.2.3 Detector

The detector used in the Model 330 Potentiometric Voltmeter consists of a dc amplifier and zero-centering meter. The amplifier is a modulator-stabilized sealed transistor circuit with input filtering and overload protection. A simplified schematic of the detector is shown in Figure 3.3.

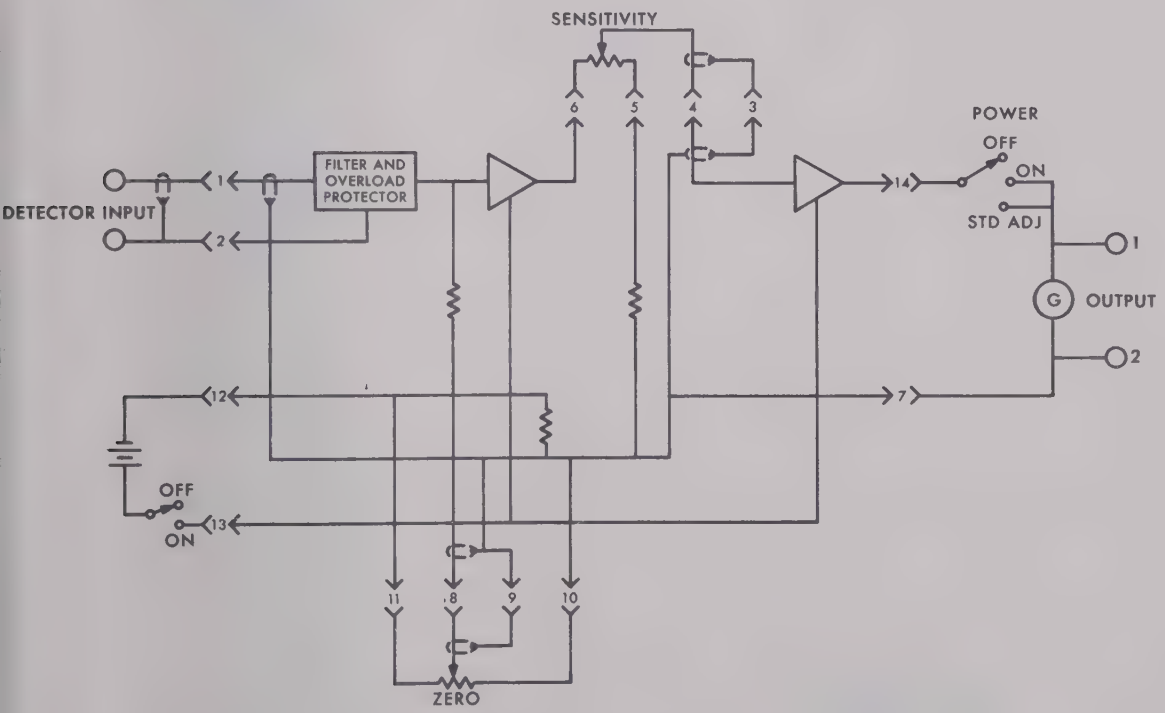



Figure 3.3 Detector Simplified Schematic

### 3.2.4 Input Attenuator

The Model 330 Potentiometric Voltmeter has a 10-megohm input attenuator to reduce high input voltages to voltages that can be compared with the working voltage reference. The attenuator consists of three resistors; a 9-megohm, a 900-kilohm and a 100-kilohm resistor connected in series. The resistors are connected across the input

voltage when the RANGE selector is on the 120-volt, or 1200-volt ranges. The output of the attenuator is one-tenth or one-hundredth of the input voltage. The attenuator output is measured potentiometrically with the same circuits that are used to measure voltages less than 12.1110 volts.

### 3.2.5 Guarding

The input of the Model 330 Potentiometric Voltmeter is guarded to prevent leakage resistance from causing incorrect readings. When the instrument is operating in one of the potentiometric ranges; 120-millivolt, 1200-millivolt, or 12-volt ranges; the input is guarded at the voltage of the main decade output. This means that at null, the voltage drop across the insulation on or supporting the input terminal and test lead is zero. Since the voltage drop is zero, there is no leakage current, and thus no error due to leakage.

When the instrument is operating in one of the higher ranges, 120-volt or 1200-volt ranges, the input is guarded at the potential of the LO terminal. In this way, the leakage is all across the input attenuator, and can have no effect on the measurement.

# SECTION IV

# MAINTENANCE

The Model 330 Potentiometric Voltmeter will require very little maintenance unless it is subjected to extreme conditions of temperature, shock, or rough handling. The only periodic maintenance that will be necessary is checkout, battery replacement, and standard cell calibration. Checkout and standard cell calibration procedures should be performed every two months if 0.001% standard cell accuracy is required, or any time that there is reason to suspect that the instrument has been damaged.

Calibration of the main decade linearity and of the ranges requires special high-precision equipment. It is advisable not to attempt these procedures unless such equipment is available. If the equipment is available, the procedures should be performed sixty days after receipt of the instrument and annually thereafter.

The checkout procedure may be used as a validation procedure if validation is required. The checkout procedure is a guide to alignment and trouble-shooting. Do not make adjustments or attempt to repair unless the instrument does not meet the requirements set forth in the checkout procedure.

If the need for major repairs is apparent, it is recommended that the instrument be returned to the factory for service and repair. Our Service Department will be glad to furnish necessary repair information as well as replacement parts. Unauthorized repairs will invalidate the warranty on the equipment.

## 4.1 CHECKOUT

The checkout procedure consists of mechanical checks and electrical self-checks.

### 4.1.1 Mechanical Checks

(1) Inspect the instrument for damage. Check binding posts, NULL DETECTOR meter, dials and switches, case hinges and latches, and carrying handle for damage.

(2) Check the toggle switch. DETECTOR switch should operate and remain in INT and EXT positions when it is so set.

(3) Check ZERO, SENSITIVITY, and STD ADJ controls. Controls should turn freely.

(4) Check POWER, RANGE, and POLARITY switches. Turn each of the switches fully counter-clockwise. The pointers should be in the following positions: POWER switch at OFF position, RANGE switch at 120 MILLIVOLTS, POLARITY switch at +.

(5) Check the main decade dials for alinements. The numbers on the dials should be centered in the windows. Turn main decade dial A counter-clockwise; the number indicated should be 0. Turn each of the other main decade dials through a complete revolution. There should be no detent between X and 0 positions.

(6) Check the binding posts. All binding post caps should be present, and should be removable. The gold-plated caps should be on the binding posts that are labeled GRD.

(7) Check the decimal point positions and the RANGE window. Turn RANGE control through all positions. The indication in the RANGE window should be centered and the decimal point should completely cover one window when the RANGE switch is in each position. Turn RANGE selector fully counter-clockwise. The indication in the RANGE window should be MILLIVOLTS, and the decimal point should be in the second decimal point position.

4.1.2 Null Detector Sensitivity Test

(1) Turn on power and stabilize.
(2) Adjust Detector zero.
(3) Connect a test lead between UNKNOWN HI and LO terminals.
(4) Set main decade dials to 00.300 and RANGE selector to 120 MILLIVOLTS.
(5) Standardize working voltage.
(6) Set DETECTOR switch to INT; the NULL DETECTOR should indicate full scale or more.

4.1.3 Stability Test

Stabilize the Model 330 Potentiometric Voltmeter at a constant temperature for at least six hours before performing the stability test, and maintain the same temperature during the test. The temperature may be any temperature between 40°F and 140°F (between 5°C and 57°C), but the change of temperature should not be more than 2°F (1.1°C) per hour during the stabilization period.

(1) Turn on power and stabilize.
(2) Adjust detector zero.
(3) Standardize working voltage.
(4) Do not change any control on the instrument for 30 minutes.

After 30 minutes, turn POWER selector to STD ADJ and DETECTOR switch to INT. The NULL DETECTOR indications should be less than full scale.

4.1.4 Main Decade Self-Check

This test verifies that the pairs of resistance decades are matched within the specified tolerance.

(1) Turn on power and stabilize.
(2) Adjust detector zero.
(3) Set all main decade dials to zero.
(4) Set RANGE selector to 12 VOLTS.
(5) Set DETECTOR switch to INT.
(6) Set POWER switch to STD ADJ position.
(7) Be sure SENSITIVITY control is fully clockwise.
(8) Adjust STD ADJ control for NULL DETECTOR zero indication.
(9) Turn main decade dial E slowly clockwise until NULL DETECTOR indication changes suddenly. This position will be between 0 and 1 on the dial, between detents.

(10) Note the amount of NULL DETECTOR deflection. This deflection is the tolerance for the following steps.
(11) Set decade dial E to 0.
(12) Set DETECTOR switch to OFF.
(13) Turn main decade dial B one step clockwise.
(14) Set DETECTOR switch to INT. The NULL detector indication should be smaller than the tolerance established in step 10.
(15) Repeat steps 12, 13, and 14 for each step of main decade dial B, and for each step of dials C and D.

## 4.2 CALIBRATION

The calibration procedures consist of standard cell calibration, range calibration, and main decade linearity calibration.

The following table lists equipment necessary to perform calibration procedures of the Model 330 Potentiometric Voltmeter.

| EQUIPMENT | USE | RECOMMENDED MODEL |
|---|---|---|
| Standard cell | To calibrate internal standard cell | Certified saturated cadmium standard cell |
| Stable, high-resolution 1000v, 100v, 10v, and 1v voltage source | To calibrate ranges | Kintel Model 303 or Hewlett-Packard 740 |
| Voltage divider or Volt box | To calibrate ranges | ESI Model 1040A, or ESI Model 1045 |
| Resistance Measurement System | To calibrate main decade | ESI Model 242 and ESI Model SR 1010, 1k per step and 10k per step |

### 4.2.1 Standard Cell Calibration

The reference voltage in the Model 330 Potentiometric Voltmeter is a thermally lagged unsaturated standard cell. In order to maintain 0.001% accuracy of the standard cell, it should be calibrated every 60 days. Calibrate by measuring the voltage of a certified saturated cadmium standard cell. Perform the following adjustment procedure only if the measured voltage differs from the certified voltage by more than one step of main decade dial E (0.001%). Do not make unnecessary adjustments.

(1) Remove battery compartment cover for access to standard cell adjustment control.
(2) Turn on power and stabilize.
(3) Adjust detector zero.
(4) Set RANGE selector to 1200 MILLIVOLTS.
(5) Set main decade dials to the certified voltage of the standard cell. Main decade dial A should be set at 10 and main decade dial B should be set at 1.
(6) Set POLARITY switch to +.
(7) Connect UNKNOWN VOLTAGE terminals to standard cell, HI terminal to positive standard cell terminal.
(8) Set DETECTOR switch to INT.
(9) Adjust STD ADJ control on front panel for NULL DETECTOR zero indication.
(10) Set POWER switch to STD ADJ and adjust standard cell adjustment control in battery compartment for NULL DETECTOR zero indication.

(11) Set POWER switch to ON and make sure that NULL DETECTOR indicates zero.

(12) Disconnect instrument from standard cell and replace battery compartment access door.

### 4.2.2 Range Calibration

In order to calibrate the ranges of the Model 330 Potentiometric Voltmeter, it is necessary to use a voltage divider or volt box with one-to-one, ten-to-one, and hundred-to-one ratios that are calibrated to within few parts per million. It is also necessary to use a voltage source that has short-term stability of few parts per million, has one-part-per-million resolution, and has output voltages of approximately 1 volt, 10 volts, 100 volts, and 1000 volts. An external detector with one-microvolt sensitivity should be used to calibrate the 120-millivolt range.

The range adjustment potentiometers are factory set, and should not be adjusted unless the above equipment is used, nor should they be adjusted unless the calibration procedure shows an error of more than one switch step of main decade dial E.

A. Remove instrument case (paragraph 4.3.2) so that adjustment potentiometers (Figure 4.1) can be adjusted.

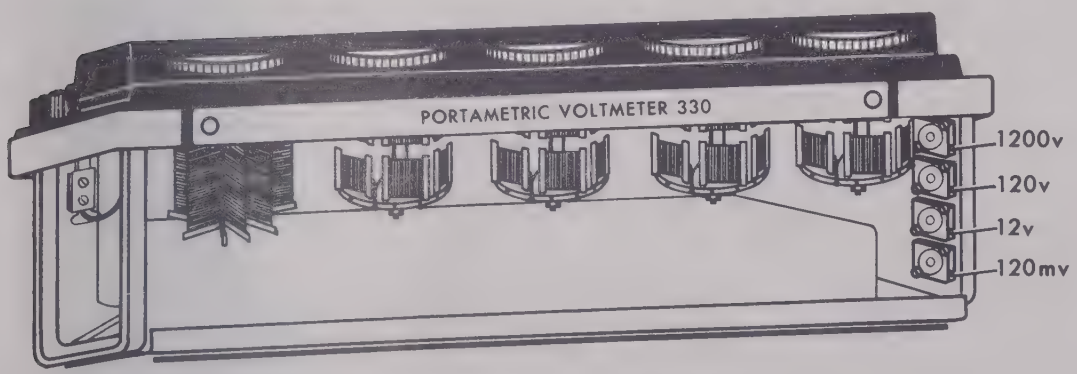



Figure 4.1 Adjustment Potentiometer Locations

B. Turn on power and stabilize.

C. Adjust detector zero.

D. Connect voltage source to input of voltage divider. Figure 4.2 shows typical calibration connection.

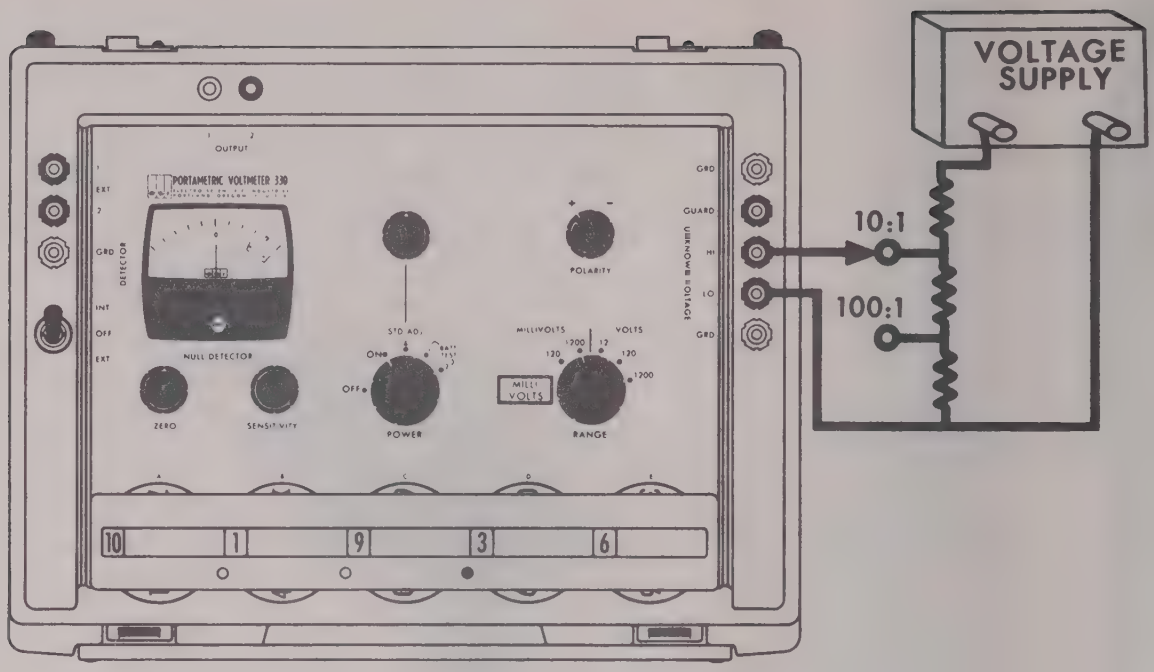



**Figure 4.2 Typical Calibration Connection**

E. Calibrate 12-volt range:
   (1) Set voltage source output to 10 volts (±10%).
   (2) Connect Model 330 Potentiometric Voltmeter to one-to-ten ratio output of voltage divider.
   (3) Measure voltage with Model 330. Make measurement with 1200-millivolt range.
   (4) Set POWER switch to STD ADJ and standardize working voltage (Step F in instrument lid instructions).
   (5) Adjust voltage source for exact NULL DETECTOR zero.
   (6) Set DETECTOR switch to OFF and RANGE selector to 12 VOLTS.
   (7) Set POWER switch to STD ADJ and standardize working voltage again (Step F in instrument lid instructions).
   (8) Connect Model 330 to output of voltage source. Use main decade dial E to check the voltage; if NULL DETECTOR zero indication is within one switch step of previous setting, do not make the following adjustments, proceed to step F.
   (9) Set POWER switch to ON and DETECTOR switch to INT. Adjust STD ADJ control for NULL DETECTOR zero.
   (10) Set POWER switch to STD ADJ, set DETECTOR switch to OFF, and adjust detector zero.
   (11) Set DETECTOR switch to INT and adjust 12-volt range adjustment (Figure 4.1) for NULL DETECTOR zero.
   (12) Set DETECTOR switch to OFF to check detector zero.
   (13) Repeat Step 2, set RANGE selector to 1200-MILLIVOLTS, and set DETECTOR switch to INT.
   (14) If NULL DETECTOR does not indicate zero in steps 10 and 11, repeat procedure from step 3.

F. Calibrate 120-volt range:
   (1) Set voltage source output to 100 volts (±10%)
   (2) Connect Model 330 Potentiometric Voltmeter to one-to-one-hundred ratio output of voltage divider.
   (3) Measure voltage with Model 330. Make measurement with 1200-millivolt range.
   (4) Set POWER switch to STD ADJ and standardize working voltage (Step F in instrument lid instructions).
   (5) Adjust voltage source for exact NULL DETECTOR zero.
   (6) Set DETECTOR switch to OFF and RANGE selector to 120 VOLTS.
   (7) Set POWER switch to STD ADJ and standardize working voltage again (Step F in instrument lid instructions).
   (8) Connect Model 330 to output of voltage source. Use main decade dial E to check the voltage; if NULL DETECTOR zero indication is within one switch step of previous setting, do not make the following adjustments, proceed to step G.
   (9) Set POWER switch to ON and DETECTOR switch to INT. Adjust STD ADJ control for NULL DETECTOR zero.
   (10) Set POWER switch to STD ADJ, set DETECTOR switch to OFF, and adjust detector zero.
   (11) Set DETECTOR switch to INT and adjust 120-volt range adjustment (Figure 4.1) for NULL DETECTOR zero.
   (12) Set DETECTOR switch to OFF to check detector zero.
   (13) Repeat step 2, set RANGE selector to 1200-MILLIVOLTS, and set DETECTOR switch to INT.
   (14) If NULL DETECTOR does not indicate zero in steps 10 and 11, repeat procedure from step 3.

G. Calibrate 1200-volt range:
   (1) Set voltage source output to 1000 volts (±10%).
   (2) Connect Model 330 Potentiometric Voltmeter to one-to-one-hundred ratio output of voltage divider.
   (3) Measure voltage with Model 330. Make measurement with 12-volt range.
   (4) Set POWER switch to STD ADJ and standardize working voltage (Step F in instrument lid instructions).
   (5) Adjust voltage source for exact NULL DETECTOR zero.
   (6) Set DETECTOR switch to OFF and RANGE selector to 1200 VOLTS.
   (7) Set POWER switch to STD ADJ and standardize working voltage again (Step F in instrument lid instructions).
   (8) Connect Model 330 to output of voltage source. Use main decade dial E to check the voltage; if NULL DETECTOR zero indication is within one switch step of previous setting, do not make the following adjustments, proceed to step H.
   (9) Set POWER switch to ON and DETECTOR switch to INT. Adjust STD ADJ control for NULL DETECTOR zero.
   (10) Set POWER switch to STD ADJ, set DETECTOR switch to OFF, and adjust detector zero.
   (11) Set DETECTOR switch to INT and adjust range adjustment (Figure 4.1) for NULL DETECTOR zero.
   (12) Set DETECTOR switch to OFF to check detector zero.

(13) Repeat step 2, set RANGE selector to 12-VOLTS, and set DETECTOR switch to INT.
(14) If NULL DETECTOR does not indicate zero in steps 10 and 11, repeat procedure from step 3.

H. Calibrate 120-millivolt range:

NOTE: If an external detector is normally used with the instrument in order to provide greater sensitivity, the same detector should be used in the following procedure. Use a fully floating detector or floating voltage supply if possible in order to avoid ground loops. See paragraph 2.3.1 for external detector connections. The following procedure describes the use of the internal detector. If an external detector is used, substitute the phrase "external detector" for "NULL DETECTOR" in steps 4, 7, 9, and 12; substitute "EXT" for "INT" in steps 8 and 11.

(1) Set voltage source output to 1 volt (±10%).
(2) Connect Model 330 Potentiometric Voltmeter to output of voltage source.
(3) Measure voltage with Model 330. Make measurement with 1200-millivolt range.
(4) Set POWER switch to STD ADJ and standardize working voltage (Step F in instrument lid instructions).
(5) Adjust voltage source for exact NULL DETECTOR zero.
(6) Set DETECTOR switch to OFF and RANGE selector to 120 MILLIVOLTS.
(7) Set POWER switch to STD ADJ and standardize working voltage again (Step F in instrument lid instructions).
(8) Connect Model 330 to one-to-ten ratio output of voltage divider. Use main decade dial E to check the voltage; if NULL DETECTOR zero indication is within one switch step of previous setting, do not make the following adjustments, proceed to step I.
(9) Set POWER switch to ON and DETECTOR switch to INT. Adjust STD ADJ control for NULL DETECTOR zero.
(10) Set POWER switch to STD ADJ, set DETECTOR switch to OFF, and adjust detector zero.
(11) Set DETECTOR switch to INT and adjust range adjustment (Figure 4.1) for NULL DETECTOR zero.
(12) Set DETECTOR switch to OFF to check detector zero.
(13) Repeat step 2, set RANGE selector to 1200-MILLIVOLTS, and set DETECTOR switch to INT.
(14) If NULL DETECTOR does not indicate zero in steps 10 and 11, repeat procedure from step 3.

I. Replace the instrument case and turn off power before leaving the instrument.

### 4.2.3 Main Decade Calibration

Calibration of the main decade consists of determining and recording the corrections to be applied to measurements for each setting of the main decade dials. The corrections are expressed in terms of fractions of one step of main decade dial E. If ten-part-per-million accuracy is sufficient, the corrections need not be applied to measurements, and the calibration procedure may be considered as a check to ensure that the linearity of the main decade is as specified.

The calibration consists basically of three parts: (1) calibration of the resistance measurement system, (2) measurement of the resistance of the first two main decades, and (3) calculation of the linearity correction for the decades.

The resistance measuring system may be calibrated relative to any resistance standard since the calibration is to determine resistive linearity rather than absolute resistance. The procedure described here uses the first resistor measured as a standard, and uses ESI Model SR 1010 Resistance Standards to establish resistance ratios and to calibrate the measuring system.

A proper choice of measurement equipment will reduce calculation of linearity. The procedure described here uses an ESI Model 242 Resistance Measuring System because of its accuracy and ability to reduce calculations.

Calculation of linearity is made with respect to the resistance of the main decade when the dials are set to 10 0 0 0 0. Linearity difference is the difference between the measured resistance of a setting and the resistance of the fraction of the reference resistance that the setting represents. Since the reference resistance is the resistance of the main decade with the dials set to 10 0 0 0 0, the linearity difference of a setting of 5 0 0 0 0 is the difference between the measured resistance of the main decade with a dial setting of 5 0 0 0 0 and one-half the resistance of the main decade with the dials set to 10 0 0 0 0.

Since main decade dial E is the one-ohm-per-step dial, the correction in fractions of a step of dial E is equal to the linearity difference, but has the opposite sign.

The work sheets included are for the calibration as outlined.

A. Calibrate resistance measuring system.

| | |
|---|---|
| 1. Measure resistance of first resistor R1 in 1k-per-step Model SR 1010. | It is assumed that the operator is familiar with the Model 242 measuring system. Set deviation dial to 0, balance detector with Model RS925 Resistance Standard. |
| 2. Determine deviations of other resistors in 1k-per-step SR 1010. Record deviations in Column B of work sheet. | Leave Model RS925 as set, measure with deviation dial. |
| 3. Compute total and cumulative resistance deviations and record in Columns C and D of work sheet. | Cumulative deviation is the sum of the deviations divided by the number of resistors; i.e., the cumulative deviation of the third resistor is the sum of the deviations of the first three resistors divided by three. |

4. Calibrate measuring system at 10 kilohms using ten resistors of 1k-per-step SR 1010.

   Set deviation dial to cumulative deviation of the ten resistors determined in previous step. Connect bridge to first ten resistors of 1k-per-step SR 1010. Set RS 925 to balance bridge.

5. Determine deviations of resistors in 10k-per-step SR 1010. Record deviations in Column B of work sheet.

6. Compute total and cumulative resistance deviations and record in Columns C and D of work sheet.

7. Set Model 240 Bridge to 0.1x STANDARD. Determine the system deviations with respect to the Model SR 1010 Resistance Standards. Measure SR 1010 resistances with the RS 925 set to the nominal value of the resistances. Record the deviations in Column F of the work sheet.

   Set the Model RS 925 to 9999.9 (TEN) to measure 2 kilohms, and so forth. Balance the bridge with the deviation dial.

8. Compute the system corrections and record them in Column G of the work sheet.

   Subtract the cumulative deviation of the SR 1010 from the system deviation; that is, subtract algebraically the numbers entered in Column D of the work sheet from the numbers entered in Column F.

B. Measure the resistances of the first two main decades of the Model 330 and compute the linearity correction.

1. Prepare the Model 330 for measurement; set POWER selector to OFF, set RANGE selector to 12 VOLTS, set DETECTOR switch to OFF, and set main decade dials to 0.0 0 0 0 1.

2. Measure the resistance between UNKNOWN VOLTAGE LO terminal and EXT DETECTOR terminal 2. Record the measurement on the first line of Column I of the work sheet.

   This resistance is the zero resistance. It will be slightly higher than one ohm. The one-ohm value simplifies later calculations.

| | |
|---|---|
| 3. Set the main decade of the Model 330 to 10.0 0 0 1 and standardize the measuring system. | Set RS925 to 999(TEN)00.0 plus the zero resistance, set deviation dial to the value recorded in Column G and balance the detector with the lead correction screwdriver adjustment. This step subtracts the deviations of this setting from all later readings. |
| 4. Measure the main decade resistance for all dial settings listed in Column H of the work sheet. Subtract the nominal value (Column 1E) from the reading and record the difference in Column I. | Set deviation dial to settings listed in Column G of work sheet and balance with RS925. Use nines for as many of the first digits as possible so that the readings will be near the points at which the system was calibrated. |
| 5. Subtract the zero resistance from each figure noted in Column I and record the difference in Column J. | The tolerance of the values listed in Column J are listed in Column K. These tolerances reflect the specified accuracy of 10 ppm of reading plus 1 ppm of full scale. |

## 4.3 TROUBLESHOOTING

If the Model 330 Potentiometric Voltmeter does not function properly, observe all the symptoms before removing the instrument case. The checkout procedures are useful for finding symptoms. Paragraphs 4.1.1, 4.1.2, and 4.1.3 are self-check procedures and require no external equipment.

### 4.3.1 Troubleshooting Table

The following table lists symptoms and probable causes of troubles. In almost all cases, only one probable cause listed in the table will fit all symptoms of a trouble; it is the most probable cause.

| SYMPTOM | PROBABLE CAUSE |
|---|---|
| ZERO control will not adjust NULL DETECTOR pointer to zero. | Defective Detector Module<br>Defective Detector Meter<br>Defective ZERO control potentiometer |
| Detector sensitivity is too low (paragraph 4.1.3). | Defective Detector Module<br>Defective Detector Meter<br>Defective SENSITIVITY control potentiometer |
| No NULL DETECTOR indication when POWER switch is in BATT TEST position. | Defective battery<br>Defective battery holder<br>Defective detector meter<br>Defective POWER switch |
| Reversed NULL DETECTOR indication when POWER switch is in BATT TEST position. | Battery of dry cell installed with reversed polarity |
| No NULL DETECTOR indication when measuring voltage or performing sensitivity test. (Be sure that RANGE and POLARITY selectors are set properly, that POWER switch is in ON position and that DETECTOR switch is in INT position.) | Defective detector module<br>Defective meter<br>Defective DETECTOR switch<br>Detective POWER switch |
| No external detector indication when measuring voltage with external detector connected.<br>(1) Internal detector operates properly.<br>(2) Internal detector does not operate properly. | <br><br>Defective DETECTOR switch<br><br>Defective POWER switch<br>Defective DETECTOR switch |

| SYMPTOM | PROBABLE CAUSE |
|---|---|
| Standardized voltage not stable (paragraph 4.1.4). | Defective regulated voltage supply |
| STD ADJ control cannot be adjusted so that NULL DETECTOR indication is zero. (Be sure that POWER switch is in STD ADJ position.) | Defective STD ADJ control potentiometer<br>Defective standard cell<br>Defective standard cell adjustment potentiometer<br>Defective POWER switch<br>Defective regulated voltage supply |
| Standard cell adjustment control (in battery compartment) will not adjust NULL DETECTOR indication to zero during calibration (paragraph 4.1.7). | Defective standard cell<br>Defective standard cell adjustment potentiometer |
| Main decade indications are not linear, or one main decade dial reading is manifestly false. | Defective main decade resistor<br>Defective main decade switch |
| NULL DETECTOR gives no indication or main decade indications are incorrect for certain settings of RANGE selector. | Defective RANGE selector switch<br>Defective range resistor |
| Ratio resistor calibration adjustments will not correct range discrepancy. | Defective range resistor<br>Defective range adjustment potentiometer |

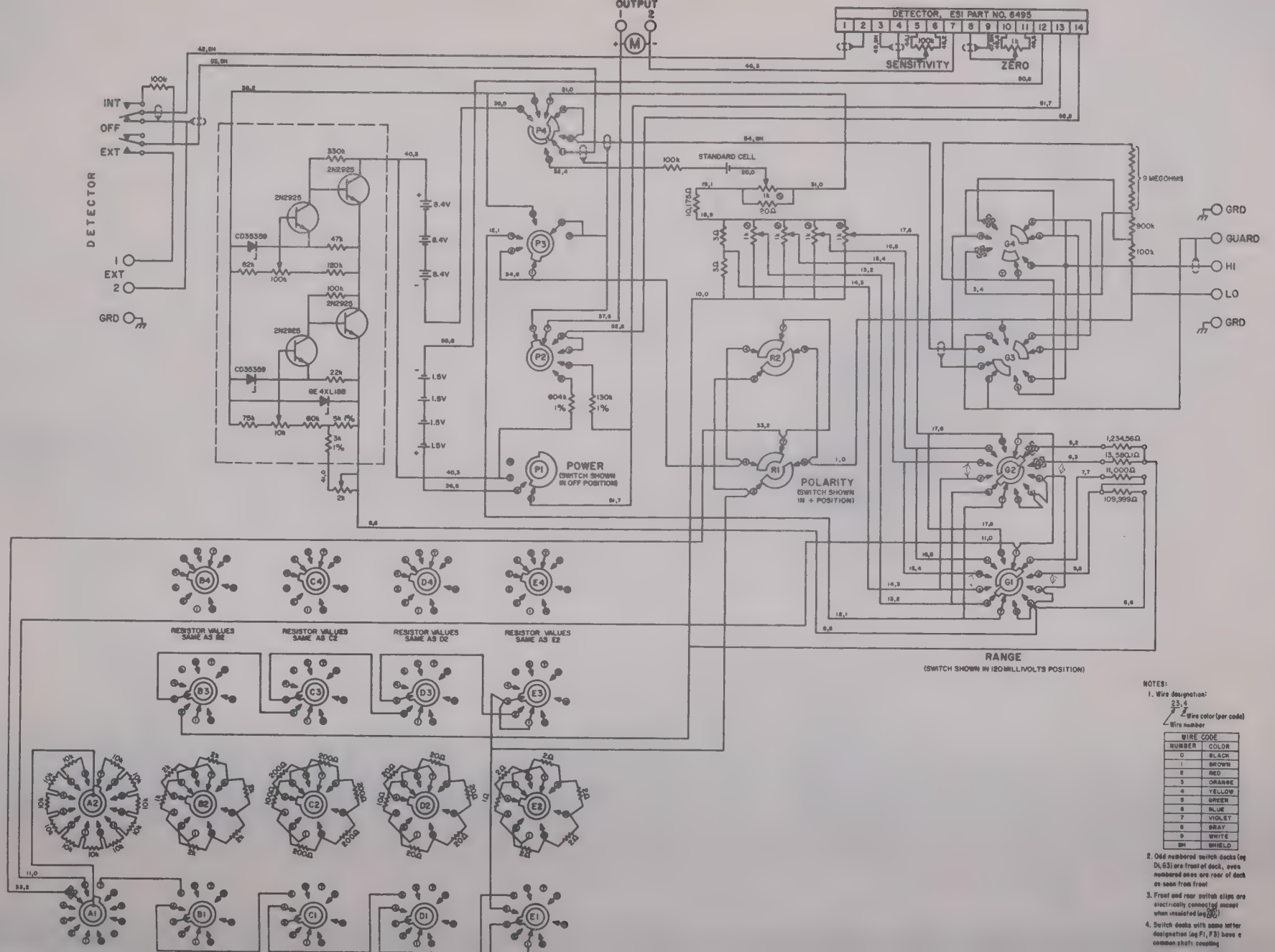
### 4.3.2 Removing the Instrument Case

Prepare a clean smooth area on which the instrument can be set face down. Be sure that there will be no pointed objects or projections under the instrument panel.

Place the instrument face-down on the prepared area. Remove four screws from the bottom of the instrument. It is not necessary to remove the battery cover or the rubber feet from the instrument. Lift the instrument case straight up.

### 4.3.3 Wiring Diagram

Figure 4.3 is a wiring diagram that will be useful for trouble-shooting and repair.




NOTES:

1. Wire designation:

   23.4 / 2 — Wire color (per code); Wire number

| WIRE CODE | |
|---|---|
| NUMBER | COLOR |
| 0 | BLACK |
| 1 | BROWN |
| 2 | RED |
| 3 | ORANGE |
| 4 | YELLOW |
| 5 | GREEN |
| 6 | BLUE |
| 7 | VIOLET |
| 8 | GRAY |
| 9 | WHITE |
| SH | SHIELD |

2. Odd numbered switch decks (eg D1, G3) are front of deck, even numbered ones are rear of deck as seen from front
3. Front and rear switch clips are electrically connected except when insulated (eg 2G1)
4. Switch decks with same letter designation (eg F1, F3) have a common shaft coupling

## 4.4 REPLACEMENT PARTS

The following parts list is in alphabetical order by the description of the part. It is recommended that parts not on this list be replaced or repaired at the factory. When ordering replacement parts, please include the following information:

Model and Serial Number of the Instrument

ESI Part Number

Description of Part

Quantity Required

| DESCRIPTION | PART NO. | QTY USED |
|---|---|---|
| Battery, 1.5 volt, D | 5267 | 4 |
| Battery, 8.4 volt, Mercury | 6198 | 3 |
| Battery Tray Assembly | 18130 | 1 |
| Binding Post, Small Shoulder | 1480 | 1 |
| Binding Post, Superior, 1 inch long | 1396 | 2 |
| Cap, Binding Post, Gold-Plated | 1172 | 3 |
| Cap, Binding Post, Insulated, Black | 1170 | 4 |
| Cap, Binding Post, Insulated, Gray | 1188 | 1 |
| Case | 6574 | 1 |
| Clip, Mercury Battery | 6565 | 2 |
| Detector Assembly[1] | 6495 | 1 |
| Dial, 0 - to - X | 6465 | 4 |
| Dial, 0 - to - 11 | 18092 | 1 |
| Door, Battery Access, Less Instruction Sheet | 6558 | 1 |
| Front Panel | 18090 | 1 |
| Gasket, Bezel | 6794 | 2 |
| Instruction Manual | 18083 | 1 |
| Instruction Sheet, Battery Replacement | 18125 | 1 |
| Instruction Sheet, Plastic Laminated | 18084 | 1 |
| Jack, Banana, Insulating, Black | 2540 | 1 |
| Jack, Banana, Insulating, Red | 2518 | 1 |
| Knob, Large Bar, Filled | 1266 | 2 |
| Knob, Small Bar, Filled | 1270 | 1 |
| Knob, Small Round | 1255 | 1 |
| Knob, Small Round, Filled | 1268 | 2 |

[1] Trade-in allowance is made for defective detector assembly.

| DESCRIPTION | PART NO. | QTY USED |
|---|---|---|
| Lid, with Hardware, without Instruction Sheet | 6479 | 1 |
| Mask, Dial, without Decimal Light Pipes | 18093 | 1 |
| Meter | 6452 | 1 |
| Mylar Tube, for D Cells | 6840 | 1 |
| Mylar Tube, for Mercury Batteries | 6841 | 1 |
| Paper, Luminous, Red | 2328 | 3 |
| Potentiometer, 1k, Linear, ZERO | 6577 | 1 |
| Potentiometer, 100k, Logarithmic, SENSITIVITY | 6576 | 1 |
| Potentiometer, Ten Turn, STD ADJ | 6547 | 1 |
| Potentiometer, Trim, 1k, Standard Cell Calibrate | 6579 | 1 |
| Printed Circuit Board Assembly consisting of: | 18101 | 1 |
| Diode, Zener, 6.8 volts | 1780 | 2 |
| Diode, Zener, Z4XL81B | 1793 | 1 |
| Heat Sink | 18121 | 1 |
| Potentiometer, Trim, 100k | 9235 | 1 |
| Potentiometer, Trim, 100k | 18114 | 1 |
| Printed Circuit Board | 18086 | 1 |
| Resistor, 100k, 1/2 watt, ± 5% | 1951 | 1 |
| Resistor, 47k, 1/2 watt, ±10% | 1958 | 1 |
| Resistor, 220k, 1/2 watt, ±10% | 1965 | 1 |
| Resistor, 3k, 1/2 watt, ± 1% | 2066 | 1 |
| Resistor, 5k, 1/2 watt, ± 1% | 2071 | 1 |
| Resistor, 22k, 1/2 watt, ±10% | 2453 | 1 |
| Resistor, 82k, 1/2 watt, ± 5% | 6159 | 1 |
| Resistor, 120k, 1/2 watt, ± 5% | 18122 | 1 |
| Resistor, 75k | 18145 | 1 |
| Resistor, 60k | 18146 | 1 |
| Transistor, 2N2925 | 6467 | 4 |
| Resistor, 100Ω, ±0.05%, Third Decade | 9725 | 2 |
| Resistor, 200Ω, ±0.05%, Third Decade | 9724 | 10 |
| Resistor, 9.999Ω, ±0.05%, Fourth Decade | 9727 | 2 |
| Resistor, 19.999Ω, Fourth Decade | 9726 | 10 |
| Resistor, 0.999Ω, Fifth Decade | 9744 | 2 |
| Resistor, 1.999Ω, Fifth Decade | 9728 | 10 |
| Resistor, 10k, First Decade[2] | 18144 | 11 |
| Resistor, 1k, Second Decade[2] | 18142 | 2 |
| Resistor, 2k, Second Decade[2] | 18143 | 10 |

[2]Because unusual skill and experience are required, the instrument should be returned to the factory for repair or modification to the first or second decades.

| DESCRIPTION | PART NO. | QTY USED |
|---|---|---|
| Resistor, 130k, 1/2 watt, ±1% | 1777 | 1 |
| Resistor, 604k, 1/4 watt, ±1% | 18112 | 1 |
| Rod, Decimal Light Pipe | 18096 | 3 |
| Shorting Lug | 3247 | 1 |
| Shoulder Washer, Binding Post, Insulating | 8823 | 4 |
| Sleeve, Stainless Steel, 0.63 in. long, for Guarded Binding Post | 1479 | 1 |
| Sleeve, Stepped Diameter, Lexan, for Guarded Binding Post | 1486 | 1 |
| Standard Cell Assembly | 6578 | 1 |
| Switch, First Decade[2] | 18106 | 1 |
| Switch, Second through Fifth Decades[2] | 6461 | 4 |
| Switch, FUNCTION, 2 Section, Five Position | 18104 | 1 |
| Switch, POLARITY, 1 Section, Two Position | 18105 | 1 |
| Switch, POWER, 2 Section, Five Position | 18103 | 1 |
| Terminal Board Assembly consisting of: | 18115 | 1 |
| Potentiometer, Trim, 1k | 18113 | 4 |
| Resistor, 3Ω | 18132 | 2 |
| Resistor, 10,175Ω | 18133 | 1 |
| Resistor, 100k | 18135 | 1 |
| Resistor, 900k | 18136 | 1 |
| Resistor, 9 Meg | 18137 | 1 |
| Resistor, 1234.56Ω | 18138 | 1 |
| Resistor, 12,580Ω | 18139 | 1 |
| Resistor, 109,999Ω | 18140 | 1 |
| Resistor, 11k | 18141 | 1 |
| Resistor, 100k, ±0.1% | 18299 | 1 |
| Terminal Board with Terminals | 18108 | 1 |
| Test Lead Set | 18149 | 1 |
| Washer, No. 10, Delrin | 1276 | 1 |
| Washer, Shoulder, Delrin, No. 10 | 2245 | 1 |
| Washer, Shoulder, No. 10, Delrin 0.175 in. Thick | 1277 | 2 |
| Window, Acrylic | 18087 | 1 |

[2]Because unusual skill and experience are required, the instrument should be returned to the factory for repair or modification to the first or second decades.

641 4/4

# e|s|i. MODEL 330 CALIBRATION WORK SHEET

| A<br>ESISTOR<br>NUMBER<br>1k/STEP | B<br>e\|s\|i MODEL<br>SR 1010<br>DEVIATION | C<br>TOTAL | D<br>CUMULATIVE | E<br>NOMINAL<br>RESISTANCE | F<br>SYSTEM<br>DEVIATION | G<br>SYSTEM<br>CORRECTION | H<br>e\|s\|i<br>MODEL 330<br>SETTING | I<br>MEASURED<br>DIFFERENCE | J<br>MEASUREMENT<br>CORRECTION | K<br>TOLERANCE |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0,000 | | | 0.0001 | | 0 | |
| $R_1$ | | | | 1,000 | | | 0.1001 | | | 0.11 |
| $R_2$ | | | | 2,000 | | | 0.2001 | | | 0.12 |
| $R_3$ | | | | 3,000 | | | 0.3001 | | | 0.13 |
| $R_4$ | | | | 4,000 | | | 0.4001 | | | 0.14 |
| $R_5$ | | | | 5,000 | | | 0.5001 | | | 0.15 |
| $R_6$ | | | | 6,000 | | | 0.6001 | | | 0.16 |
| $R_7$ | | | | 7,000 | | | 0.7001 | | | 0.17 |
| $R_8$ | | | | 8,000 | | | 0.8001 | | | 0.18 |
| $R_9$ | | | | 9,000 | | | 0.9001 | | | 0.19 |
| $R_{10}$ | | | | 10,000 | | | 0.X001 | | | 0.20 |

| A<br>ESISTOR<br>NUMBER<br>0k/STEP | B<br>e\|s\|i MODEL<br>SR 1010<br>DEVIATION | C<br>TOTAL | D<br>CUMULATIVE | E<br>NOMINAL<br>RESISTANCE | F<br>SYSTEM<br>DEVIATION | G<br>SYSTEM<br>CORRECTION | H<br>e\|s\|i<br>MODEL 330<br>SETTING | I<br>MEASURED<br>DIFFERENCE | J<br>MEASUREMENT<br>CORRECTION | K<br>TOLERANCE |
|---|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | | 10,000 | | | 1.0001 | | | 0.2 |
| $R_2$ | | | | 20,000 | | | 2.0001 | | | 0.3 |
| $R_3$ | | | | 30,000 | | | 3.0001 | | | 0.4 |
| $R_4$ | | | | 40,000 | | | 4.0001 | | | 0.5 |
| $R_5$ | | | | 50,000 | | | 5.0001 | | | 0.6 |
| $R_6$ | | | | 60,000 | | | 6.0001 | | | 0.7 |
| $R_7$ | | | | 70,000 | | | 7.0001 | | | 0.8 |
| $R_8$ | | | | 80,000 | | | 8.0001 | | | 0.9 |
| $R_9$ | | | | 90,000 | | | 9.0001 | | | 1.0 |
| $R_{10}$ | | | | 100,000 | | | 10.0001 | | 0 | |
| $R_{11}$ | | | | 110,000 | | | 11.0001 | | | 1.2 |

NOVEMBER 1966

# ESI® INSTRUCTION MANUAL CHANGES

Model 330 Potentiometric Voltmeter

Instruction Manual dated April 1966

Page 4-10, Subsection 4.2.3, Step A, Substep 7: Change right-hand column to read as follows:

> Set the Model RS 925 to 9999.9 (TEN) to measure 1 kilohm, to 19999.9 (TEN) to measure 2 kilohms, and so forth. Balance the bridge with the deviation dial.

Part No. 108083-2

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| Calibration of a Decade Transformer, N. E. Morrison, Presented at AIEE Summer and Pacific General Meeting, June 1959 (revised April 1960) | EB-20 |
| Calibration of a Kelvin-Varley Voltage Divider, Dr. Merle L. Morgan and Jack C. Riley, Presented at Conference on Standards and Electronic Measurements, June 1960 | EB-24 |
| DC and Low Frequency AC Ratio Measurements, Dr. Merle L. Morgan, Presented to Study Group on Standards of Electrical Measurement, AIEE Instrumentation Division, April 1962 (revised September 1962) | EB-29 |
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| High Frequency Accuracy of 250 and 290A, December 1960 (revised) | EB-17 |
| Improved Technique for Establishing Resistance Ratios, R. M. Pailthorp and Jack C. Riley, Presented at Instrument-Automation Conference, Instrument Society of America, October 1962 | EB-35 |
| International System of Units and Convenient Audio Frequency Units, August 1964 (revised) | EB-26 |
| Low Input Resistance Voltage Dividers, March 1960 (revised) | EB-15 |
| Measuring Three-Terminal Capacitors, March 1962 (revised) | EB-7 |
| Metrology Seminar: Resistance Standards, Voltage Standards, Capacitance Standards, and Ratio Techniques, J. L. Thomas, George D. Vincent, Robert D. Cutkosky, and Jack C. Riley, Presented at WESCON Industrial Seminar, September 1964 | EB-43 |
| New Approach to Bridge Sensitivity, Jack C. Riley, Presented at Instrument-Automation Conference, Instrument Society of America, January 1961 (revised November 1962) | EB-23 |
| Precision Resistance Measurement—Part I, *ESI Design Ideas,* April 1960 | DI-2 |
| Precision Resistance Measurement—Part II, *ESI Design Ideas,* November 1960 | DI-3 |
| Ratio Transformer Bridge for Standardization of Inductors and Capacitors, D. L. Hillhouse and H. W. Kline, Presented at Conference on Standards and Electronic Measurement, June 1960 | TA-2 |
| Resistance Transfer Technique, Lawrence H. White, Presented at National Conference of Standards Laboratories Workshop, June 1963 (revised July 1963) | EB-34 |
| Sliding Balance When Making Inductive Measurements, May 1962 (revised) | EB-18 |
| Strength for the Weak Spot in DC Potentiometry, George D. Vincent and Marion L. Roberts, Presented at Measurement Standards Instrumentation Conference, Instrument Society of America, October 1965 | TA-9 |
| Systemetrics, A New Concept in Electrical Measurements, R. M. Pailthorp, May 1964 | EB-42 |
| Traceability of Resistance Measurements, Jack C. Riley, April 1962 | EB-30 |
| Transformer Bridge Theory and Practice, Jack C. Riley, January 1964 (revised) | EB-31 |
| Use of External Q Rheostat With Model 250, May 1962 (revised) | EB-11 |
| Voltage Divider Calibration, *ESI Design Ideas,* January 1960 | DI-1 |

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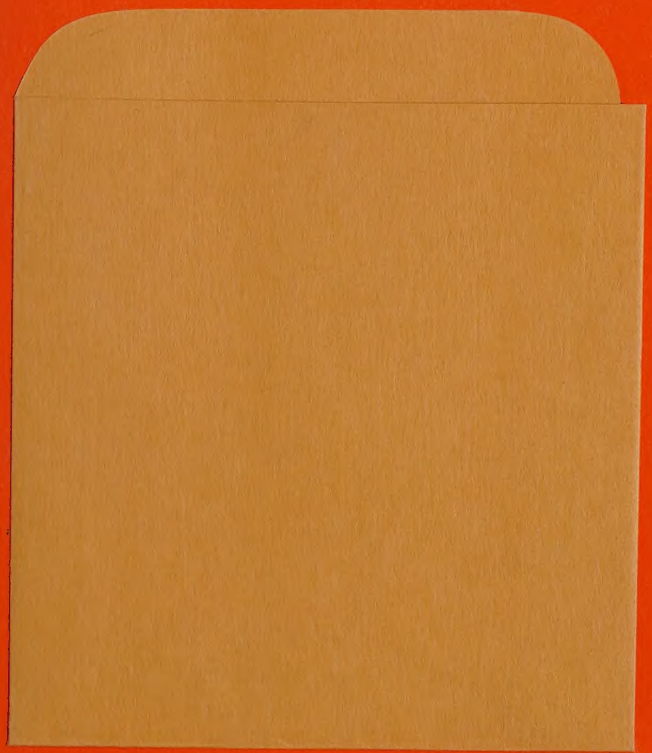

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